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**ON THE CRETACEOUS FORMATIONS OF TEXAS AND THEIR RELATION TO
THOSE OF OTHER PORTIONS OF NORTH AMERICA.**

BY CHARLES A. WHITE.

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The true relations of the different Cretaceous formations which have long been known to exist within the State of Texas to each other, and to those which have been recognized in other portions of North America, have not hitherto been satisfactorily known. Several eminent geologists have written upon the subject, and considerable diversity of opinion has prevailed among them. The former impracticability of obtaining information by personal observation over any considerable portion of that great region; the destruction by the civil war of the work so well begun by Dr. Shumard, and the limited knowledge then possessed by any one of the general geology of North America, were doubtless the causes which prevented a satisfactory solution of this question. Now numerous railroads traverse the State, the hostile tribes which barred the progress of travelers have been quieted or removed, and a good outline of the geology of the continent is known.

With the opportunity of availing myself of these advantages I entered last year upon an investigation of the Texas Cretaceous, placing the field work in charge of my chief assistant, Mr. Robert T. Hill. In the latter part of the season I traversed the State in various directions in company with Mr. Hill, reviewing his work and making additional observations. The following section is the result of these labors, and I am so well convinced of the accuracy of its essential features that I do not hesitate to adopt it as the basis of my paleontological and museum work in relation to the Texas Cretaceous, although the order of superposition therein given is so different from what it has been generally supposed to be.

The remarks at the right hand side of the column, which represents the section, are by Mr Hill, who has with considerable care compared this section with those which have hitherto been published as representing the Texas Cretaceous.

General Section of the Cretaceous Strata of the Eastern half of Texas.

GULF SERIES.	7. NAVARRO BEDS.	7. Strata in Navarro County, given this name by B. F. Shumard and correlated with the Ripley Group in 1861; but not placed in his general section of 1860; correlated with Ripley Group at Terrell by R. H. Loughridge; 10th Census Report, Vol. V. Included by Roemer, together with 4 and 5 of this section, in his "Kreidebildungen am Fusse des Hochlandes." Outcrops along a narrow area upon the western border of the Gulf States Tertiary.
	6. AUSTIN LIMESTONE.	6. Outcrops to the west of No. 7. occupying the so-called Black Prairie region. Of great thickness and uniformity of character. Recognized by Owen as extending into Arkansas, and as equivalent with the rotten limestone of Mississippi, named "Austin Limestone" by B. F. Shumard in 1860, and placed in his section between Nos. 2 and 3 of this section, but its true relation not then recognized. Included by Roemer with No. 7. Sherman, Dallas, Waco, Austin and New Braunfels are approximately upon the western border of the outcrop.
	5. EAGLE FORD SHALES.	5. Yellow arenaceous, and blue argillaceous shales, narrow exposure west, and along the northern half of No 6. Is the lower part of Shumard's Austin limestone, and also the "Arenaceous Group" and "Fish Bed" of his Lower Cretaceous.
	4. TIMBER CREEK BEDS.	4. Coarse ferruginous sands and clays; fossiliferous. Has been alluded to by various writers as "Tertiary," "Miocene," "Quaternary," etc. Its outcrop is coextensive with the region known as the Lower Cross Timbers. It apparently rests unconformably upon No. 3.
COMANCHE SERIES.	3. WASHITA DIVISION.	3. Strata of this division at Fort Washita, I. T., partially described in 1854, and called "Senonien" by G. G. Shumard, wrongly placed by B. F. Shumard, in his section, immediately beneath No. 6 of this section. More comprehensively described by Jules Marcou in 1855, and referred to the Neocöonian. Is not distinctly separable from No. 2, either by the character of the strata or fossil contents. Outcrop occupies a narrow belt extending southward from old Fort Washita via Denison. Denton, Fort Worth, Salado, Austin, and westward of San Antonio; was included together with No 2 by Roemer in his "Kreidebildungen des Hochlandes."
	2. FREDERICKSBURG DIVISION.	2. In 1848 this division was included by Roemer in his "Kreidebildungen des Hochlandes," as seen in buttes north of Fredericksburg. It is also the "Comanche Peak Group," the "Caprina Limestone" and "Caprotina Limestone" of B. F. Shumard in 1860. These authors placed all except the last named strata at the top of the whole Texas Cretaceous series. Outcrops along the borders of the paleozoic areas in Central Texas.
	1. DINOSAUR SANDS.	1. Coarse silicious sand,, popularly called "pack-sand." Occurs between the base of the fossiliferous Cretaceous and the carboniferous series. Contains vertebrate remains.

The fossils which have been collected from the strata of this Texas section, have not yet been fully studied with reference to the different formations which they represent. That work has, however, so far progressed as to give some important indications as to the equivalency of certain of these Texas formations with those which different geologists have investigated in the regions to the eastward, westward, and northward from that State; and also to show that a large part of the Texas Cretaceous section is not represented by any of the formations referred to. The following table will serve to formulate these indications, but as the recognition of equivalency is more satisfactory in some cases than in others, each case is considered separately in the following paragraphs:—

MISSISSIPPI SECTION.	TEXAS SECTION.	WESTERN SECTION.	UPPER MISSOURI RIVER SECTION.
Ripley Group. Rotten Limestone. Tombigbee Sand. Eutaw Group. Wanting. Wanting.	Navarro Beds, Austin Limestone. } Eagle Ford Shales } Timber Creek Beds. Washita Division. Fredericksb'g Division.	Fox Hills Group. Colorado Group. Dakota Group. Wanting. Wanting.	{ Nos. 4 & 5, or Ft. Pierre { and Fox Hills Groups. { Nos. 2 & 3, or Ft. Benton { and Niobrara Groups. No. 1, or Dakota Group. Wanting. Wanting.

Before making comparisons of the Texas section with the others of this table, it is necessary to make some explanations with reference to the relations of the latter to each other.

The Mississippi section indicated in the foregoing table is that which was published by Prof. E. W. Hilgard in his official report upon the geology of the State of Mississippi.¹ The western section is a modification, first proposed by King,² of the well-known Upper Missouri River section of Meek and Hayden, which is represented by the right-hand column. King, however, placed the equivalents of Nos. 3, 4 and 5 of the Upper Missouri section all together under the name of Fox Hill Group. This being an unnatural grouping of the strata upon paleontological grounds, I still further modified it by placing Nos. 2 and 3 together under King's name of Colorado Group; and Nos. 4 and 5 together under one of the original names of Fox Hills Group

¹ Geology and Agriculture of Mississippi, 1860, p. 3;

² U. S. Geol. Expl., 40th Parallel, vol. i, pp. 305, 306.

³ Ann. Report U. S. Geol. Surv. Terr. for 1876, p. 22.

These two consolidated groups, together with the Dakota Group, the separate identity of which all geologists have recognized, constitute the western Cretaceous section of the foregoing table.

The New Mexican Section of Prof. Newberry seems to be practically identical with the western section of the foregoing table.¹ He seems to indicate, however, that there is in that region a blending of the Dakota Group with the next overlying formation. It may be noted also that at least one of the species which Mr. Meek describes in that report as coming from the middle division of the New Mexican Section² is now known to belong to a lower horizon than that of the base of his section, namely, to that of the Comanche division of the Texas section.

Southward from Dakota and Montana I have never been able to separate the equivalent of No. 4 from that of No. 5 of Meek and Hayden's section, either stratigraphically or paleontologically. It is for this reason that I have referred all strata that carry any of the fossils which they indicated as characterizing either of those divisions to the Fox Hills' Group alone. On the other hand, while Nos. 2 and 3 are so closely related to each other paleontologically that they are now generally regarded as constituting one natural group, an upper and a lower lithological division of the same are quite as clearly recognizable in southern Colorado and northern New Mexico as in the Upper Missouri River region.

It is a significant fact that while the separate identity of the Dakota group has been indicated by specific identity of plant remains, which are found over a large region, as well as by stratigraphical position, there is a marked difference in the character of the invertebrate fossils from different localities. I refer especially to those which Mr. Meek³ and myself⁴ have published as coming from strata of that group in Central Kansas, as compared with the few which have been found in southeastern Dakota. The Kansas forms are mainly or wholly of marine origin, but they are such as may have lived in littoral waters; while those of southeastern Dakota are of different species, and indicate a

¹ Newberry's Geol. Rept. Expl. Exped. from Santa Fe to Junction of Grand and Green Rivers, pp. 32, 121, 122.

² *Ib.*, p. 126, pl. i, figs. 7 *a*, *b*.

³ Ann. Report U. S. Geol. Sur. Terr. for 1870, pp. 297, 301-313; Vol. IX U. S. Geol. Sur. Terr., p. 24.

⁴ Proc. U. S. National Museum, Vol. 2, pp. 295, 296, pl. 5.

less saline condition. It is also significant that, with the exception of some marine mollusca which Mr. Meek doubtfully referred to the Dakota group in New Mexico,¹ no other invertebrates than those which the Kansas and Dakota localities have furnished, have been reported as coming from that group. The facts which have been mentioned, others which will be referred to, and our present knowledge of the general geology of that western region, all seem to indicate that while the greater part of the Dakota group, as it is now known, is a non-marine deposit, we ought to expect to find it to merge into a marine deposit to the southward.

Now in making comparisons of the Texas Cretaceous rocks with those which have been observed in other parts of the continent, we find that the whole Comanche series represents older strata than are included in any of the other published sections of North American Cretaceous except perhaps that of California.² The strata of the Comanche series are known to extend northward from Texas into the Indian Territory, and some of its characteristic fossils have been found in southeastern Kansas. Fossils belonging to this series have also been found at various points in western Texas and the adjacent southeastern part of New Mexico. They have also been found at various points in Mexico, one locality being upon the western side of the Sierra Madre, in the Mexican State of Sonora.³

Judging from all the information which I have been able to obtain, I infer that none of the strata of the Comanche series extend beyond the eastern boundaries of Texas, nor further northward than southern Kansas. It seems probable also, that while this series is well developed, both faunally and stratigraphically, in Texas, it has, or originally had, its greatest development within the region which is now the Republic of Mexico.

Again, judging from present information, there seems to be a complete faunal break at the top of the Comanche series. That is, I am not yet aware that a single fossil species of that series passes up into any of the upper members of the Texas Cretaceous Section. The Comanche series is therefore not only greatly restricted in its geographical extension to the eastward and

¹ Newberry's Geol. Report before cited, p. 121.

² White; Bull U. S. Geol. Surv., No, Vol. 15, p. III, 1885.

³ Gabb; Paleontology of California, Vol. II, p. 257.

northward, but there seems also to be a clear line of demarkation between that series and the upper one, within the State of Texas. No unconformity of the strata of the upper series upon those of the latter has yet been satisfactorily observed, but it can hardly be doubted that there is at least a brief chronological break between the two series. This latter question, however, I am not now prepared to discuss.

From the foregoing remarks it will be seen that it is the formations of the upper series alone which can now be discussed with reference to equivalency with the formations represented by the other sections of the foregoing table. Beginning with the lowest member of the upper, or Gulf series, namely, the Timber Creek beds, I regard those strata as, at least in part, equivalent with the Dakota group of the Western and upper Missouri sections, and perhaps equivalent with the Eutaw group of the Mississippi section. Of the latter supposed equivalency I have no paleontological evidence; and the suggestion is made mainly in consequence of the stratigraphical position of the Eutaw group.

That the Timber Creek beds are equivalent with the Dakota group is indicated not only by the position of each with reference to overlying formations, but I have recognized some of the species which were first found in the Dakota strata of central Kansas, in the Timber Creek beds of Denton County, Texas.

The Eagle Ford shales are recognized as equivalent with the bluish shales, or lower portion of the Colorado group as it is known in Colorado and the adjoining territories. That is, I have recognized certain of the species of the Eagle Ford shales as identical with some which occur in the Colorado group to the northwestward of Texas. The lithological character of the shales of both regions is also similar.

As to the equivalency of the Eagle Ford shales with the Tombigbee sand of the Mississippi section, the only reason I now have for offering that suggestion is its stratigraphical position.

That the Austin limestone is equivalent, both stratigraphically and paleontologically, with the rotten limestone of the Mississippi section, as has been shown by other authors, there seems to be no reason to doubt. I also regard those Texan strata as equivalent with the upper division of the Colorado group. The Texan strata are not only quite similar in lithological character

to those of that division as it is known in southern Colorado and New Mexico, but I have recognized several species of fossils as common to the Austin limestone and those more northern strata.

The paleontological evidence that the Navarro beds are equivalent with the Ripley group of the Mississippi section, as presented by Shumard,¹ seems to be beyond question. It is also known that several molluscan species which characterize the equivalents of the Navarro beds in the Cretaceous of the Gulf and Atlantic coast regions, are not uncommon in the Fox Hills group of the Western section.

The Fox Hills groups of the Western section is clearly recognizable as such in the valley of the Rio Grande, in western Texas, where it is found to contain a number of the characteristic species of the group. The evidence is conclusive, also, that the Fox Hills strata there, are, or originally were, directly continuous with those of that epoch which are found to the northward.² Of the present, or former, direct stratigraphical continuity of the western Fox Hills strata with their presumed equivalents in Eastern Texas, and in the Gulf and Atlantic coast regions, present evidence is not so clear.

Although the identity of certain species, found in those eastern and western strata respectively, is beyond reasonable question, there is a decided difference, both paleontological and lithological, between them. Still, there seems to be good reason for regarding them as having been synchronously deposited. Their differences were perhaps largely due to the presence of a land area between an eastern and a western marine area during the Fox Hills-Ripley epoch, to the southward of which the two marine areas coalesced. This view seems to find corroboration in the fact that most of the species which are common to both the eastern and western strata, are open sea forms, and consequently had a wide geographical range. Those species which differ most in the two regions respectively, are apparently such as had a more restricted range.

We now come to consider the relation of the Fox Hills strata and the Navarro Beds respectively, to overlying formations. It appears to be unquestionable that the Lignite Tertiary Beds of eastern Texas rest directly upon the Navarro Beds, just as the

¹ Proc. Bost. Soc. Nat. Hist., viii, p. 189.

² This volume, pp. 18-20.

equivalent Tertiary strata rest upon the Ripley Group in Mississippi; but in Texas the actual contact seems not yet to have been seen by a competent observer. The faunal difference also, between the Navarro and the Lignite Beds, plainly indicate a change in physical conditions, and also a chronological break of some extent. The break, however, may have been only a brief one.

On the other hand, the strata of the Fox Hills Group in the region of the Rio Grande are directly overlaid by those of the Laramie Group, the two formations so blending together that no sharply defined plane of demarkation between them can be recognized. Thus we find the stratigraphical series in that western region to be an unbroken one up to the top of the Laramie Group; while the eastern series is broken at the top of the Navarro Beds. We are therefore still in doubt as to the true stratigraphical relation of the Laramie Group with the Eocene Tertiary of the Gulf region. If that relation is ever discovered, it now seems certain that we shall find it in the southwestern part of Texas, or the adjacent part of Mexico.

The Dakota Group of the western and upper Missouri sections rests directly upon Jurassic strata, which in turn rest upon a series known as the "Red Beds," and usually regarded as of Triassic age. Those Red Beds are there found to rest upon the Carboniferous, or upon older paleozoic rocks. No equivalent of the Jurassic strata referred to have been recognized in connection with the Texas Cretaceous section as given in this article; and they seem to have entirely thinned out before reaching the region of Central Texas. In that region, the strata next underlying the Comanche series are clearly either those of the Carboniferous, or of the Red Beds. The latter are not known to exist to the eastward of the Carboniferous area of Northern Central Texas, but they reach considerable thickness upon the western side of that area, where they are usually known as the Gypsum formation.

It appears from the investigations upon which this article is based that certain of the members of the Texas Cretaceous section have not heretofore been recognized, and that the true order of superposition of the formations has been misunderstood, the theoretical section of Marcou¹ being more nearly correct than any heretofore published. It also appears that while the lower

¹Proc Boston Soc. Nat. History, Vol. VIII, p. 93.

series of that section is not represented in any of the other published sections in North America, the upper series may be satisfactorily correlated with the western and upper Missouri sections; and in part, at least, with the Cretaceous formations of the Gulf, and Atlantic coast regions.

In making these investigations the really valuable work of Dr. B. F. Shumard has been adopted so far as practicable, and a large proportion of the fossil species which he published, but did not figure, have been recognized. The admirable work of Prof. Roemer also is found to be as useful to-day as it was when it was first published, forty years ago.

ON ZINC—MANGANESE, ASBESTOS.

BY GEORGE A KOENIG, PH. D.

During a visit to the Franklin Zinc Mines in 1879, I obtained from Mr. George, then Superintendent of the Trotter mine a considerable quantity of Sussexite. Among this there was some material which did not quite look like the rest, and was subjected to an investigation. This material I will designate A. After finding it of interest, I obtained from my friend and colleague, Dr. F. A. Genth, a bluish asbestiform mineral from the same locality; this will be designated as material B.

Both appear as stiff, rather columnar fibres, and effervesce with acid. But after treatment with dilute HCL, a fine silky mass of fibres remain, and these were analyzed. The needles appeared under the microscope slightly yellowish or colorless, whilst the substance in bulk appeared bluish, like crocidolite or brown black.

These needles fuse readily before the blow-pipe with intumescence to a black globule, and behave thus like Sussexite. But no color is given to the flame, so characteristically green in Sussexite.